Pediatric Hydrocephalus Part II

Shunts

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The Problem…

- Hydrocephalus occurs in approximately 1/2000 births.
- Shunt insertion is the most common neurosurgical operation.
- Median corrected age of first shunt placement is 55 days.

The solution….

CSF Shunt Hydrodynamics

- Flow dynamics underlies the function of any type of shunt
- Shunt flow is proportional to the intrinsic CSF pressure driving flow, and inversely proportional to the resistance to flow

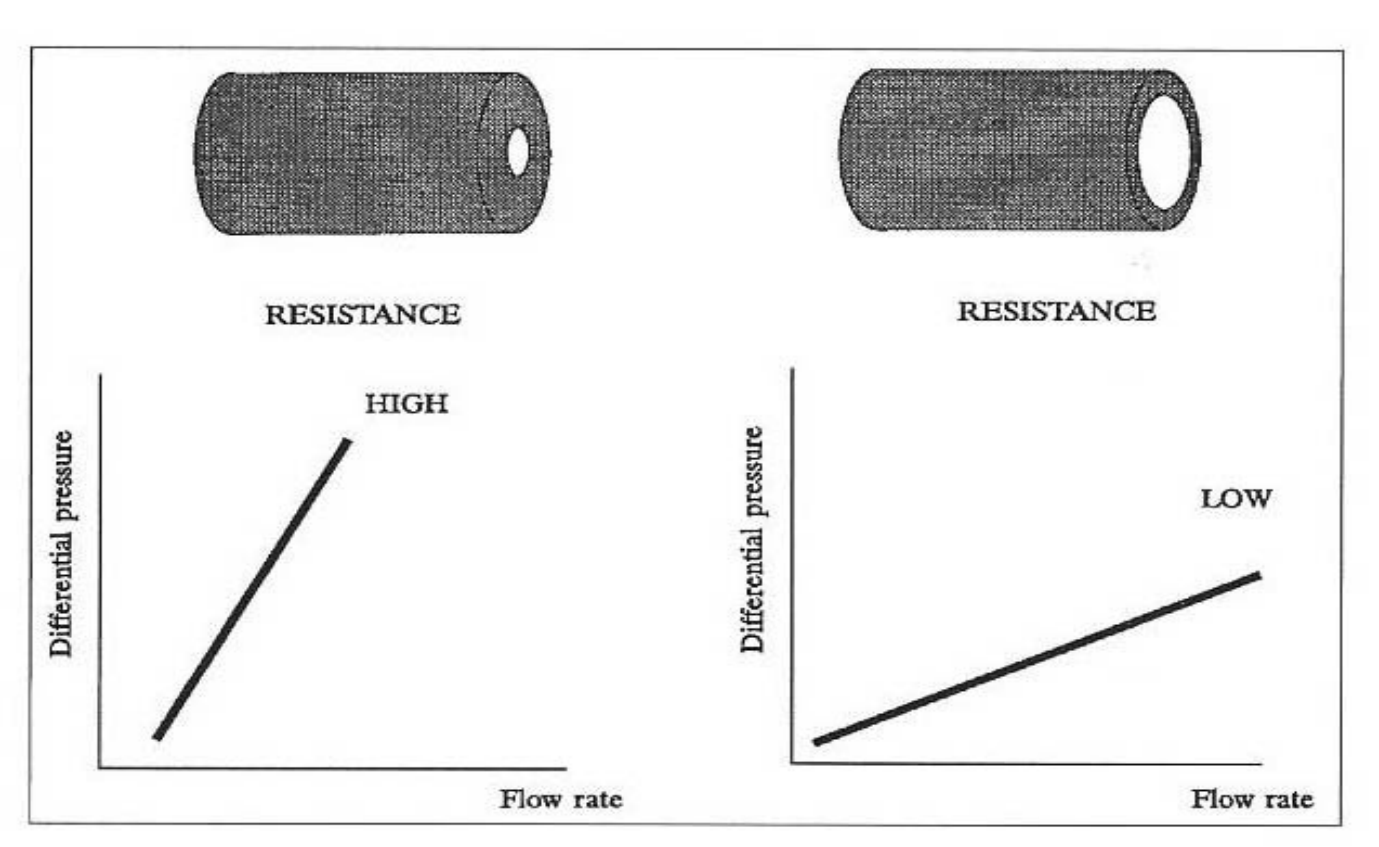
$$Q = P/R$$

CSF Shunt Hydrodynamics

- Poiseuille's Law…

$$\Delta P = \frac{8\eta L}{\pi r^4} I_V$$

CSF Shunt Hydrodynamics



CSF Shunt Hydrodynamics

- The pressure gradient driving flow…

$$P = IVP + pgh - OVP - DCP$$

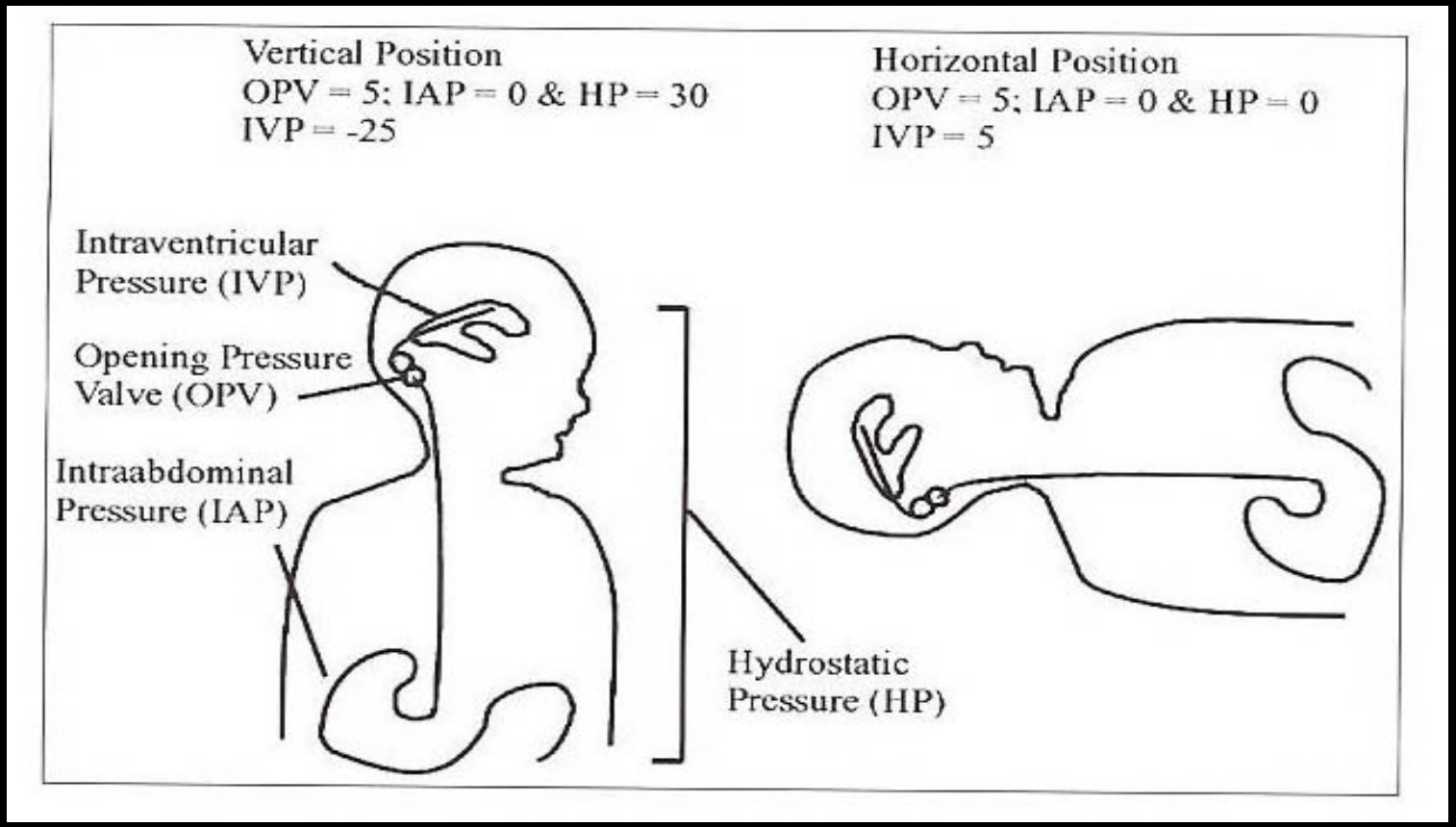
IVP = intraventricular pressure

pgh = hydrostatic pressure; density x gravitational constant x vertical height difference between distal and proximal ends

OVP= Opening pressure of valve

DCP= Distal cavity pressure

CSF Shunt Hydrodynamics



Siphoning

- Siphoning results from the hydrostatic pressure differences of the upright position.
- The average hydrostatic pressure generated in an upright patient is approx. 50cm water; even high-pressure valves only have opening pressures of 10-20cm water at best.

Siphoning

- Low-pressure systems are in danger of causing SDH, prematurely closing cranial sutures, or causing slit-ventricle syndrome.
- Only 10-12% of patients will experience the occurrence of low-pressure symptoms.

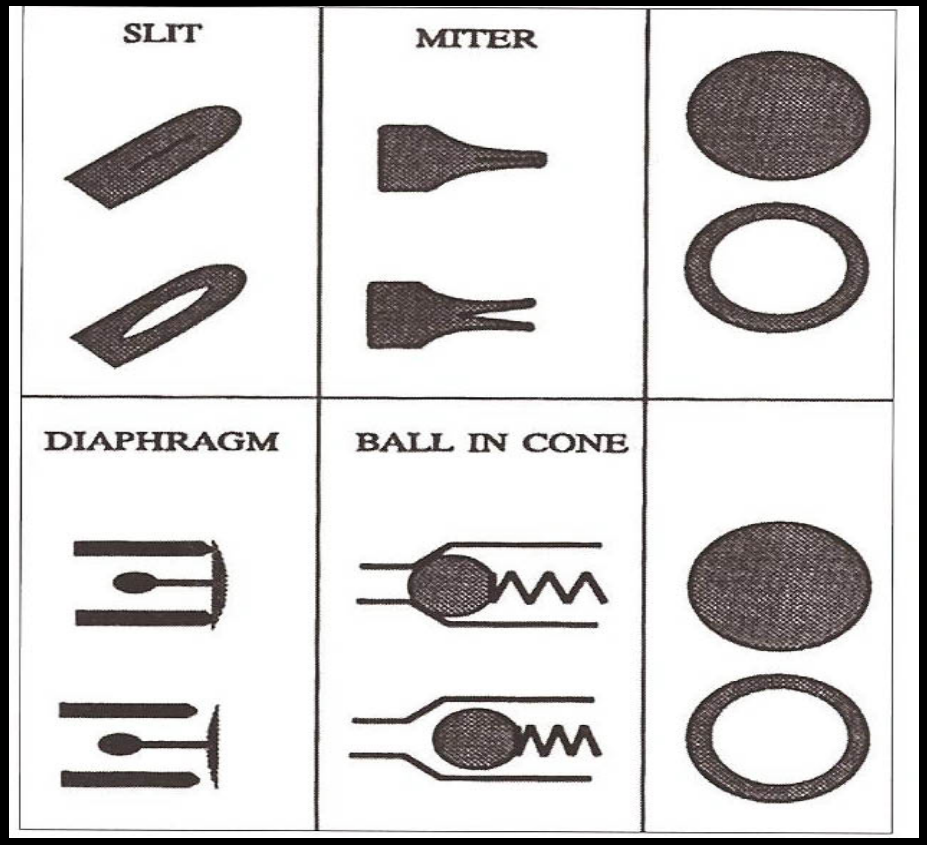
Shunt Hardware

- Valves
  - Many types
    - Differential Pressure
      - Slit
      - Miter
      - Diaphragm
      - Ball-in-cone

Low pressure valves (1-4cm OP) vs.

High pressure valves (8-10cm OP)

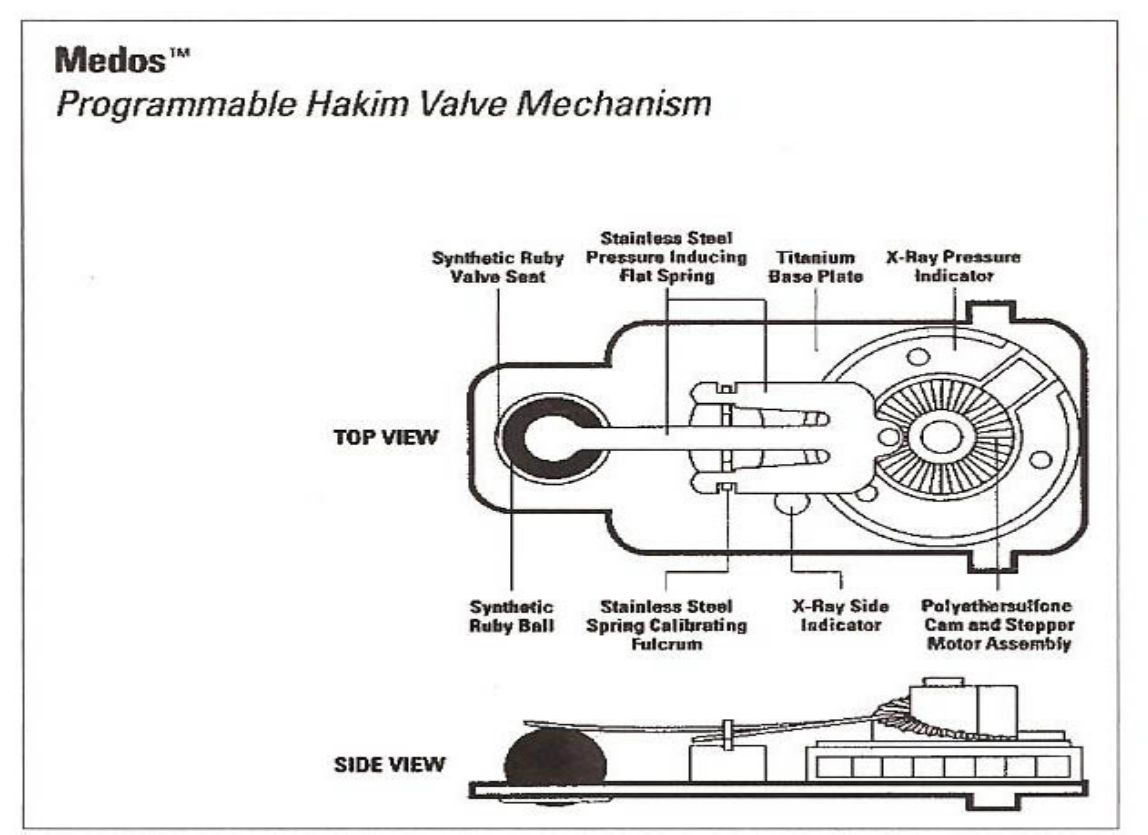
Shunt Hardware



Shunt Hardware

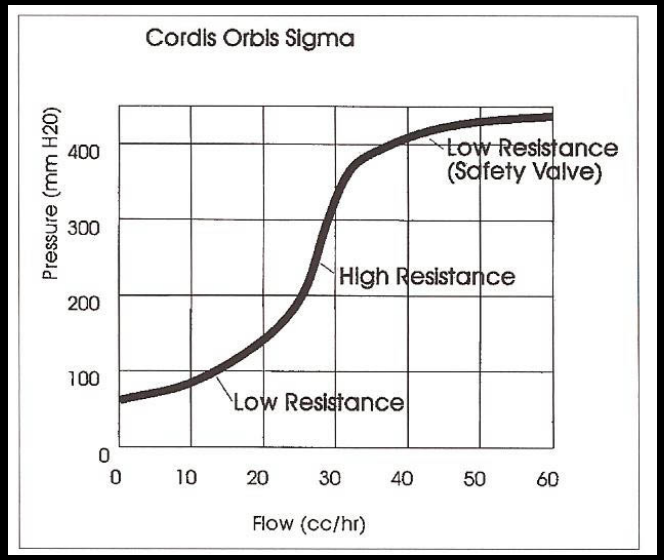
- Externally Adjustable Differential Pressure Valves (aka. Programmable valves)
  - Magnetic workings allow manipulation of OP's without invasive procedure.
  - 3-20cm OP's possible
  - May be useful in managing difficult over/under drainage, arachnoid cysts, and NPH
  - Not very MRI friendly

Shunt Hardware

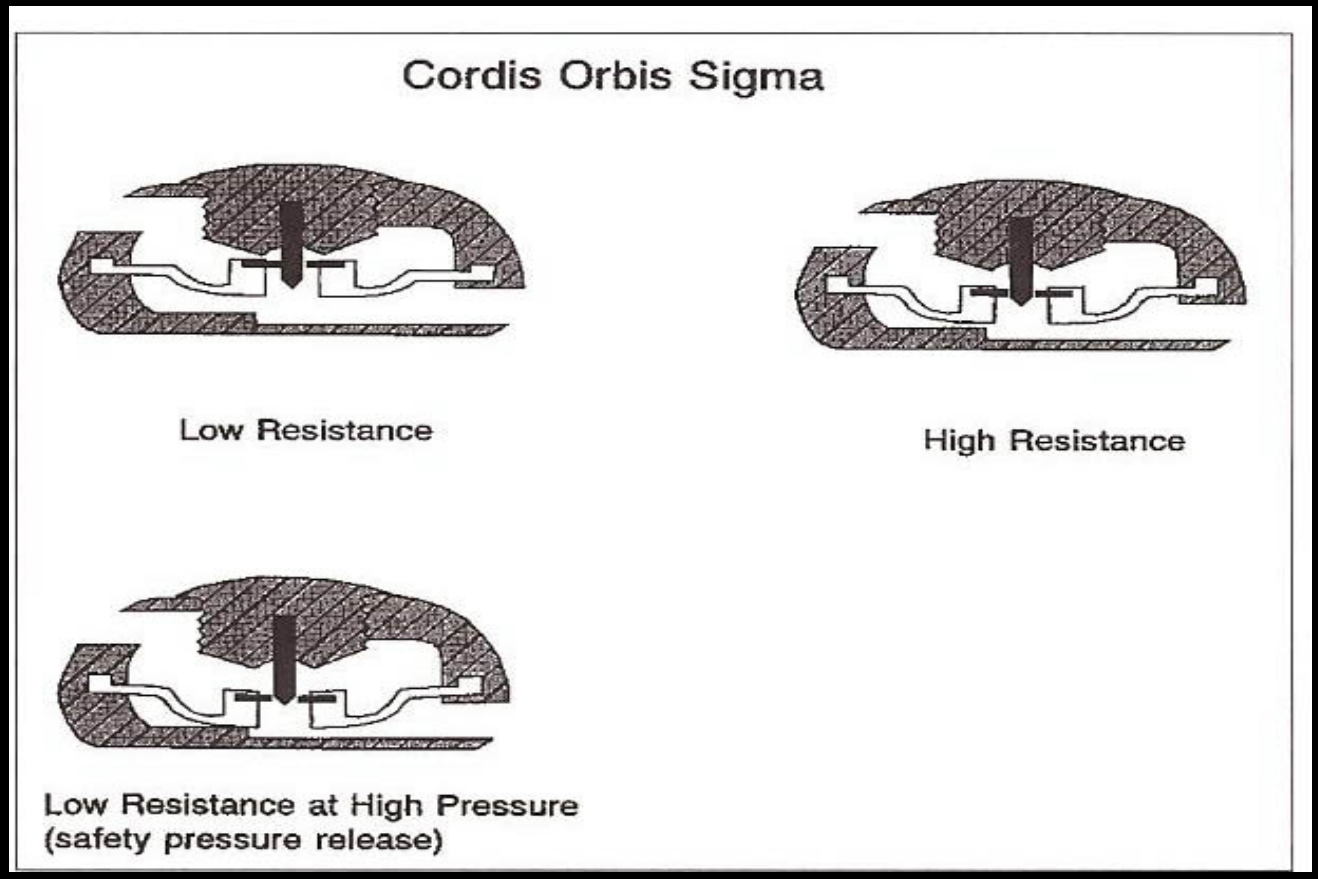


Shunt Hardware

- Flow Regulating Valves
  - Attempt to keep flow rate constant by increasing hydrodynamic resistance as pressure increases; produce sigmoid-shaped flow curves

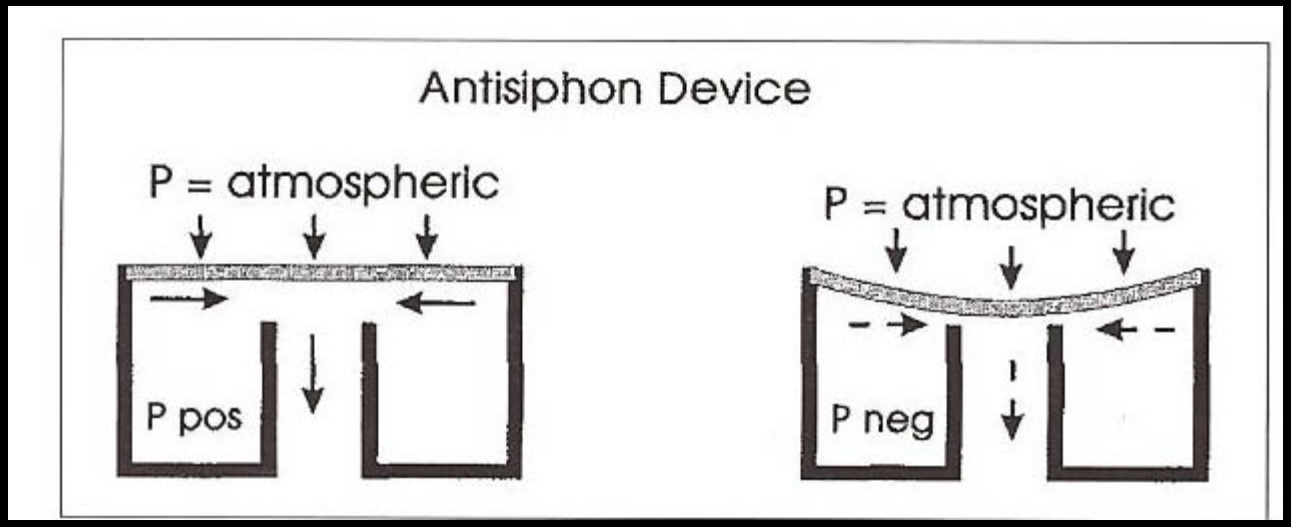


Shunt Hardware



Shunt Hardware

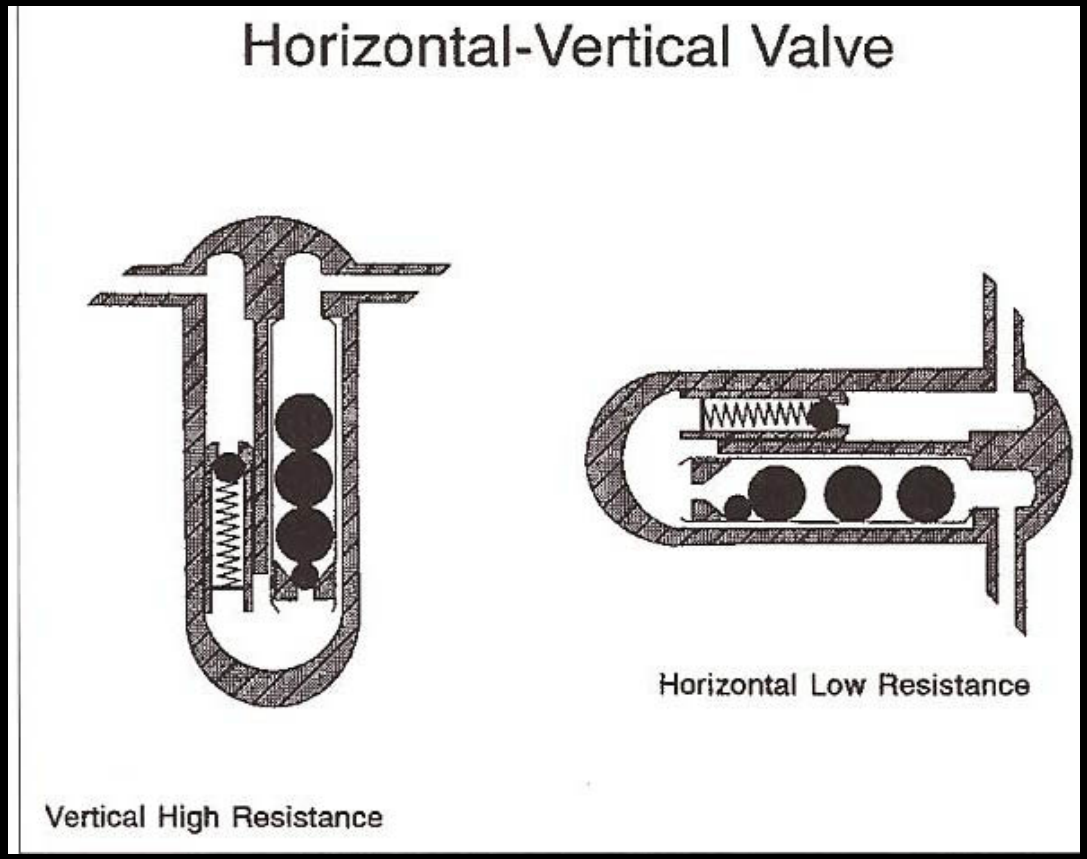
- Antisiphon Devices
  - Uses a membrane, exposed to atm pressure, to regulate against excess siphoning



Shunt Hardware

- Gravity Actuated Valves
  - Designed such that the opening pressure of the valve increases when the patient stands

Shunt Hardware



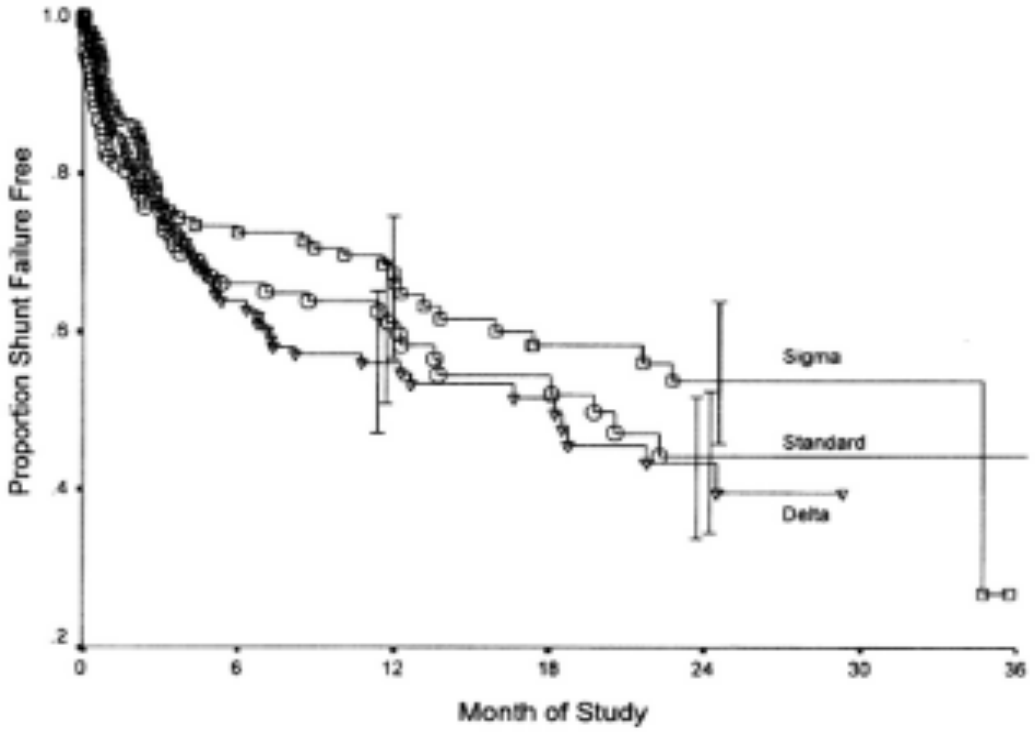
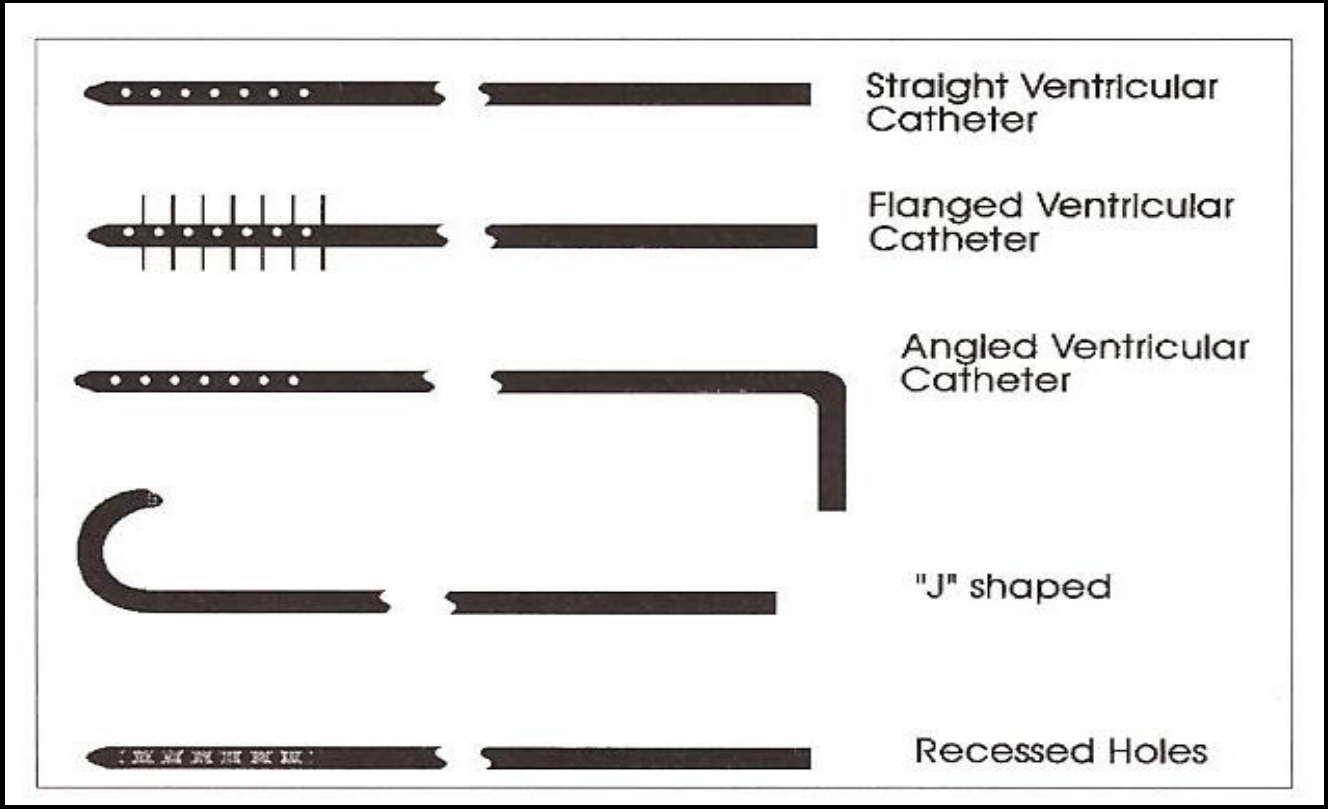


FIGURE 2. *Shunt complication-free survival curves showing a prospective, randomized shunt design trial, which compared standard valves with the Orbis Sigma Valve (Cordis, Miami, FL) and the Delta valve (Medtronic, Goleta, CA). There were no differences between the three valve designs* (from, *Drake JM, Kestle J, Milner R, Cinalli G, Boop F, Piatt J, Haines S, Schiff SJ, Cochrane DD, Steinbok P, MacNeil N: Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus. Neurosurgery 43:294–305, 1998 [20]).*

Shunt Hardware

- Proximal and Distal Catheters
  - Range from 1.0 – 1.6mm
  - Many types
  - No proven superiority; flanged-type may promote ingrowth of choroid plexus

Shunt Hardware



Shunt Complications

Shunt Complications

- Shunt Failure
- Shunt Infection
- Slit Ventricle Syndrome

Shunt Failure

- Shunt failure rates are approximately 40% at one year, and 50% at two years
- There are many reasons for shunt failure, the most common in the pediatric population being proximal blockage (90% of failures). This is most often due to choriod.

Shunt Failure

Obstruction	30.8%
Migration/Fracture	4.9%
Misplacement	7.2%
Distal Problems	Rare
Loculation	0.5%
Over-drainage	3.8%

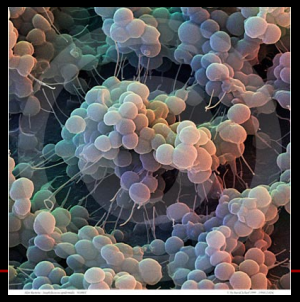
Shunt Failure

- Early Shunt Failure
  - Usually due to infection or misplacement (first few months)
- Late Shunt Failure
  - Usually due to blockage, hardware failure, over-drainage, or loculation

Shunt Failure

- The current treatment for shunt failure is the replacement of the shunt.
- A 31% risk of visible hemorrhage, either visualized in the OR or on subsequent CT, has been reported with shunt replacement.

Shunt Infection



- Infection rates for shunts reported from 1.5% to 38%
- An international prospective study of 773 patients demonstrated a 6.5% infection rate @ 1 year
- There is an up to 20% mortality rate associated with shunt infection in children

Shunt Infection

- Time to Infection
  - Approx. 92% occur with 3 months.
- Risk Factors
  - Age (>6months=17%, <6months=7%)
  - Early shunting of mylemeningiocele: >1wk increases the risk of infection 2x
  - Probable risk factors: Reason for shunt placement (congenital hydro < post-hemorrhagic, post-infectious); experience of surgeon; type of shunt (VP shunt higher than others)

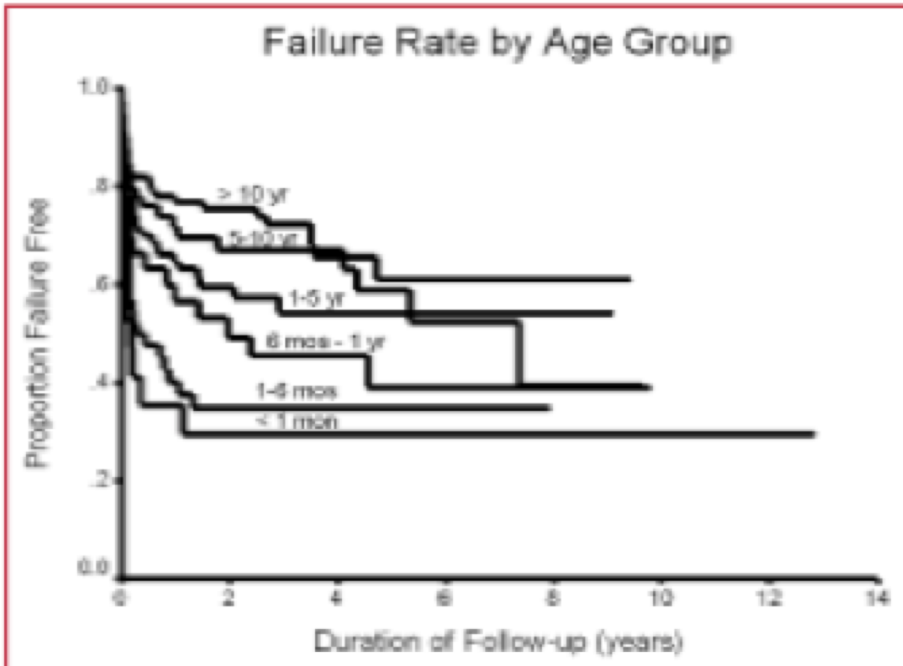


FIGURE 7. *Outcome from the Canadian collaborative study was broken down by age. There is a progressive decline in outcome with decreasing age, being lowest in children younger than 1 month of age (from, Drake JM; the Canadian Pediatric Neurosurgery Study Group: Endoscopic third ventriculostomy in pediatric patients: The Canadian experience. Neurosurgery 60:881–886, 2007 [19]).*

Shunt Infection

- Presentation
  - Headache, Lethargy
  - Nausea, Vomiting
  - Irritability
  - Fever, erythema
  - Upwards gaze palsy, papilledema
  - Abdominal Pain

Shunt Infection

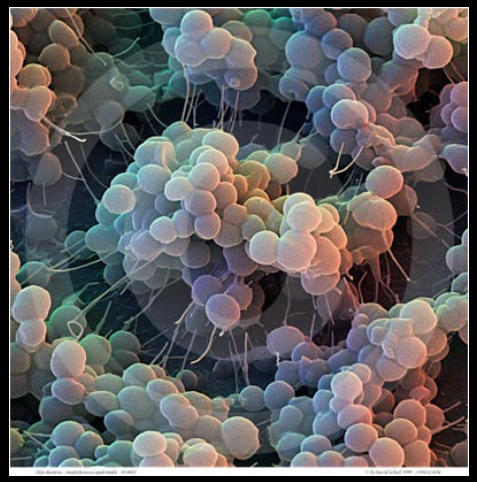
- Investigations
  - Inspection of overlying skin
  - CBC, urinalysis, blood cultures
  - X-ray (shunt series), CT, US may demonstrate fluid collections, ventriculitis
  - Shunt tapping; CSF for glucose, protein, cell count, and culture

Shunt Infection

- Prevention
  - Many theories, less evidence
  - Role of Antibiotics
    - 2 meta-analysis have demonstrated a %50 risk reduction (risk ratio 0.52, 0.48 respectively) with use of antibiotics before shunt placement (most given @ 1-2 hours pre-op, or @ induction).
    - The effect is nullified if an institutions baseline infection rate is below 15%

Shunt Infection

- Pathogens
  - Coag. –ve Staph (S. epidermis)
  - S. aureus
  - E. coli
  - Klebsiella
  - Proteus
  - Propionobacterium



Shunt Infection

- Treatment
  - Removal of hardware, antibiotics, delayed replacement of shunt hardware
  - Medical therapy is as good as placebo alone in treating shunt infection; the hardware must be removed
  - Often only the cather tip will test positive; the CSF often remains unremarkable

Shunt Infection

- Outcomes
  - Increased mortality in infected children
  - Effect on IQ
    - 73 vs 95 in infected vs. non-infected

Slit Ventricle Syndrome

Slit Ventricle Syndrome

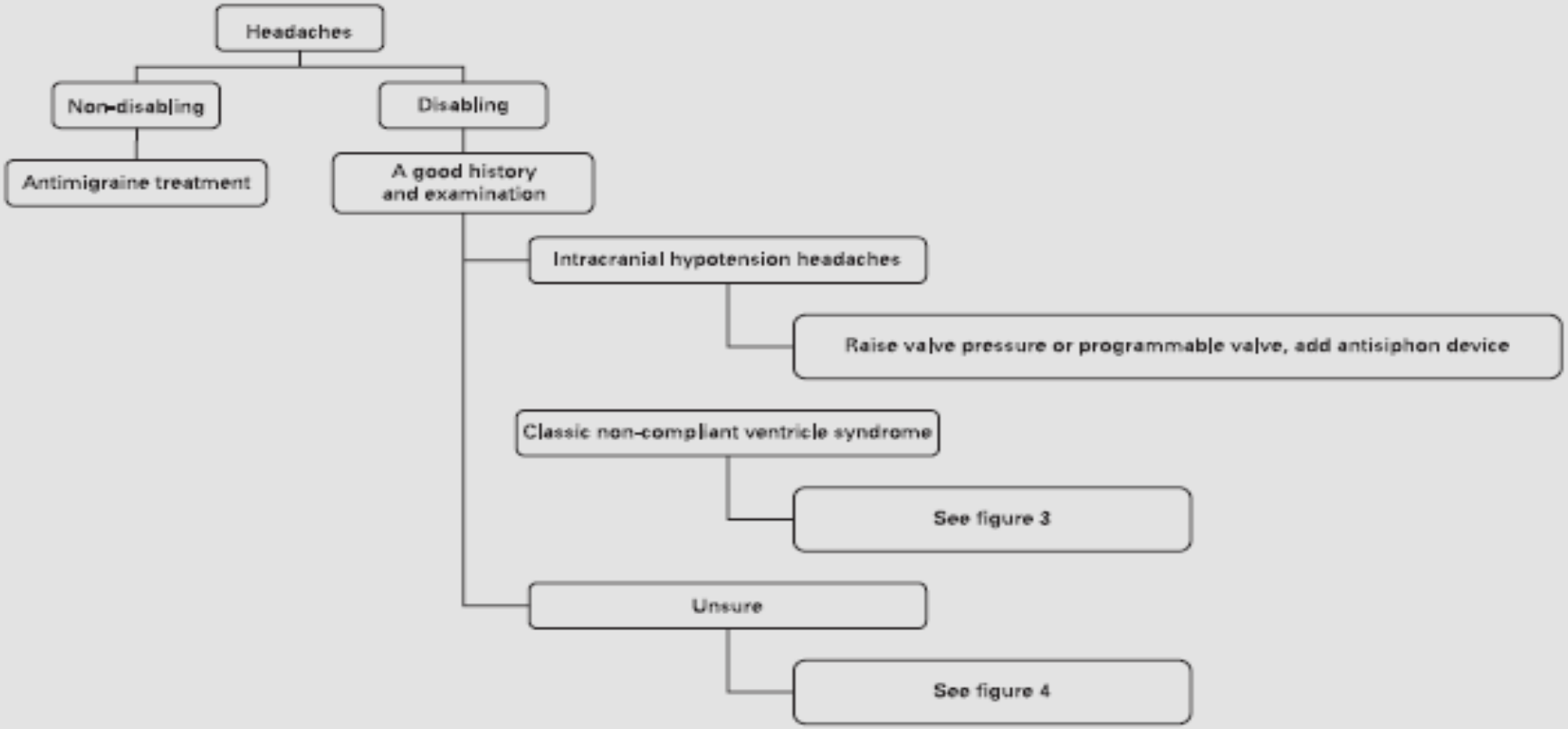
- Triad of Presentation
  - 1) Radiologic Slit Ventricles
  - 2) Intermittent SX of shunt obstruction (headache)
  - 3) Slow-refill of shunt pumping devices

Slit Ventricle Syndrome

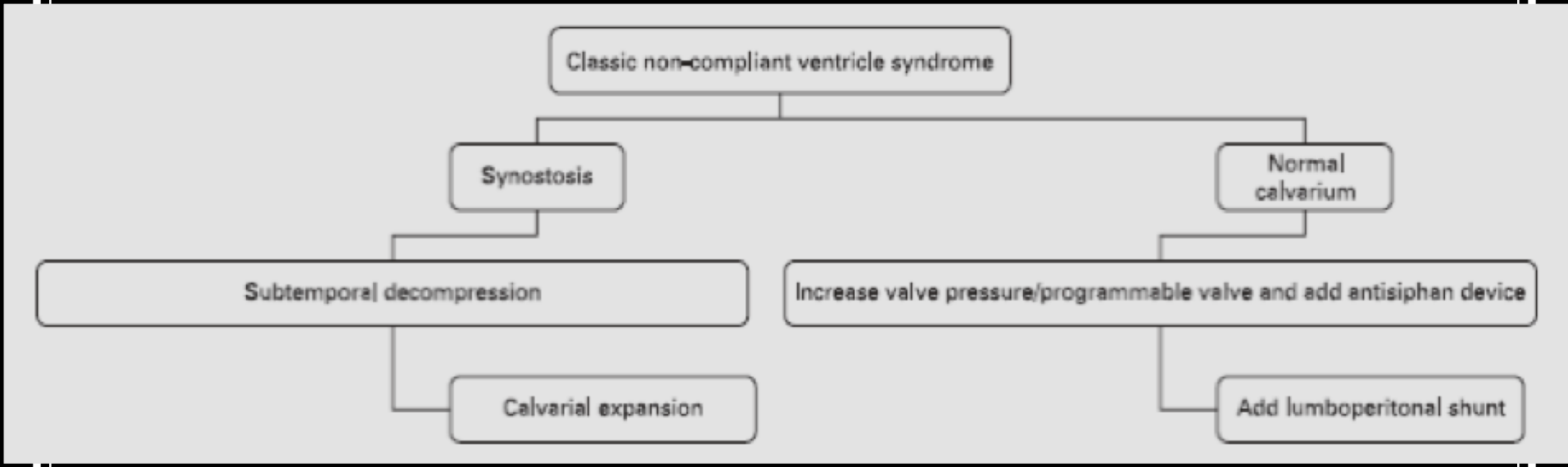
- Pathogenesis
  - Three theories
    - 1) ICP normally coupled to ventricular pressure; low ventricular pressures, increased venous congestion, and increased brain elastance.
    - 2) Hydro causes increased subependymal flow; gliosis and increased wall stiffness follows.
    - 3) Low pressure systems lead to microcephally and synostosis.

Slit Ventricle Syndrome

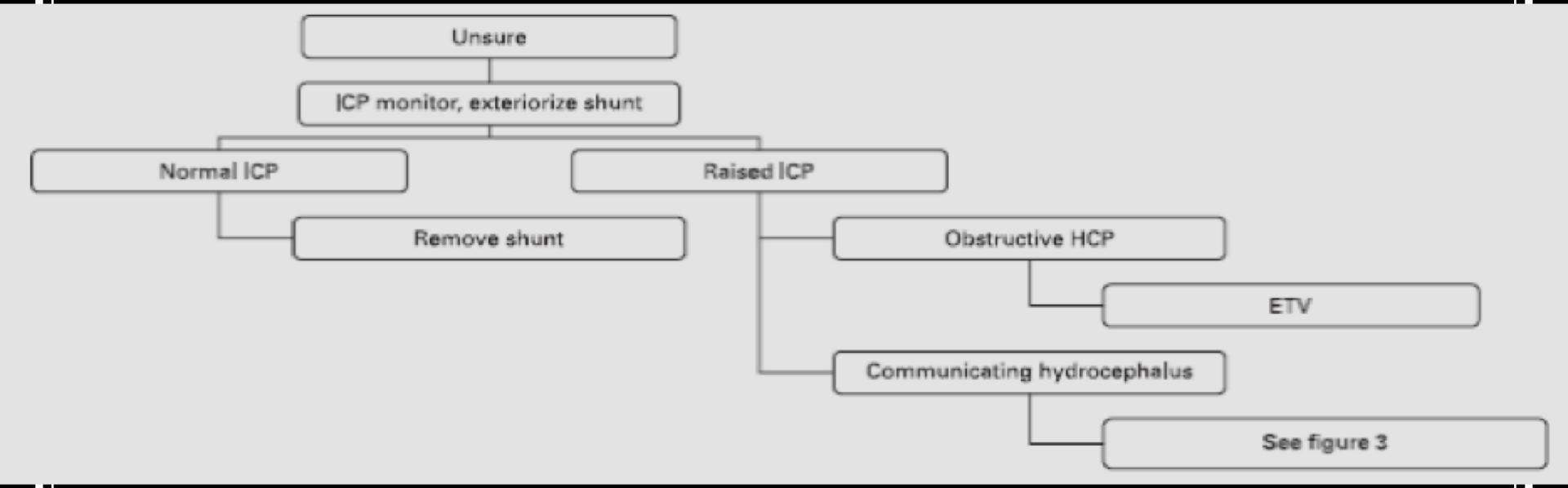
- Treatments
  - 1) Anti-migraine therapy may be beneficial
  - 2) Changing to a high-opening pressure valve or readjusting the programmable valve.
  - 3) Adding an anti-siphon device (in patients with synostosis, this may lead to pathological ICP increases)
  - 4) Decompression as a possible treatment
  - 5) Cranial expansion treatments


Headaches
Non-disabling
Disabling
Antimigraine treatment
A good history and examination
Intracranial hypotension headaches
Raise valve pressure or programmable valve, add antisiphon device
Classic non-compliant ventricle syndrome
See figure 3
Unsure
See figure 4

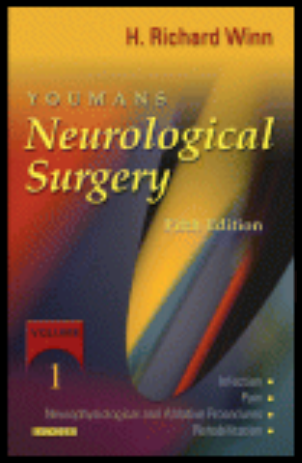
Slit Ventricle Syndrome

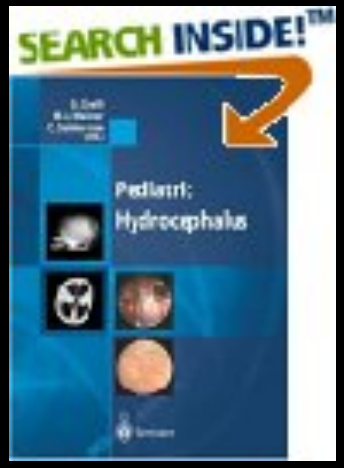


Slit Ventricle Syndrome



References





The Problematic Slit Ventricle Syndrome

A Review of the Literature and Proposed Algorithm for Treatment

Sarah Olson

Pediatr Neurosurg 2004;40:264–269
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The Slit Ventricle Syndrome: Advances Based on Technology and Understanding

Harold L. Rekate

Pediatr Neurosurg 2004;40:259–263

THE SURGICAL MANAGEMENT OF PEDIATRIC HYDROCEPHALUS

James M. Drake, F.R.C.S.C.

Neurosurgery 62[SHC Suppl 2]:SHC633–SHC642, 2008

Pediatric hydrocephalus: current management

John R.W. Kestle, MD

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Thank you!